REGRESSION COEFFICIENTS FOR COMPUTING CUBIC-FOOT VOLUME OF ROCKY MOUNTAIN TREES

by

PAUL D. KEMP
DIVISION OF FOREST ECONOMICS

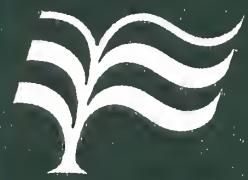# REGRESSION COEFFICIENTS FOR COMPUTING CUBIC-FOOT VOLUME
OF ROCKY MOUNTAIN TREES

Paul D. Kemp, Forester
Division of Forest Economics

This paper presents regression coefficients by species and dia-
meters used in formulas by the Forest Survey to compute partial cubic-
foot volume of trees in the Rocky Mountain area. The basic formula
used is of the form:

$$V = bx$$

where V = partial cubic-foot volume, i.e., the cubic-foot
volume inside bark from a 1-foot stump to a 4.0-
inch top d.i.b.

b = regression coefficient

$x = \dfrac{(\text{DBH in inches})^2 (\text{total height in feet from ground to tip})}{100}$

The advantages of formulas in contrast to conventional volume
tables in the determination of tree volume are: (1) they facilitate
machine operations when punch cards are used, (2) eliminate tedious
interpolations, (3) reduce unknown biases associated with grouping by
diameter and height classes, (4) permit calculation of growth to any
degree of refinement that changes in diameter and height can be meas-
ured, and (5) they facilitate the comparison between species and of
changes by species and/or inventories.

DEVELOPMENT OF BASIC FORMULA

The general approach in the development of the formulas was sug-
gested by Spurr.[1] However, contrary to Spurr's findings, the rela-
tionship between total cubic volume on D^2H for all standard cubic
volume tables tested was curvilinear--slightly within, and obviously
between, diameter classes. In dealing with partial cubic volume, i.e.,
volume between a 1-foot stump and 4-inch top inside bark, the curvi-
linearity is greatly accentuated and cannot be ignored if unbiased
estimates of volume and growth by diameter classes are required.

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[1] Spurr, Stephen H. 1951. Forest Inventory. The Ronald
Press. pp. 111-121.

Under the circumstances, only 2 alternatives were possible:
(1) a complex curvilinear formula, or (2) a modification of the simple
D^2H relationship that would introduce curvilinearity. The first, and
probably superior, alternative required more thorough study than was
warranted. Furthermore, the gain in a complex formula may be more
than offset by disadvantages in its use. The second alternative was
adopted. At the risk of introducing some subjectiveness which is in-
herent in free-hand curves, curvilinearity was allowed for by varying
the regression coefficients by diameter class. In other words, in-
stead of a single equation for a species, volumes are determined by
a series of harmonized equations. The number in this series is de-
termined by diameter intervals of 0.1 inch and coefficient intervals
of .001. Further refinements are possible by carrying additional
places in the coefficients.

The procedure of using a series of harmonized equations by diameter
class, however, accounts only for curvilinearity between diameter classes.
To account for the smaller curvilinearity within diameter classes, i.e.,
by height classes, the same procedure could be followed by setting up
additional equations. In this proposal, the curvilinearity within dia-
meter classes is ignored and volume is derived by the simple equation
of the form $V = bx$, where $b =$ the regression coefficient, and $x = D^2H/100$.
This equation tends to underscale short trees and overscale tall trees
to a maximum of about $\pm$ 3 percent. A slightly better fit (but still
straightline) could be obtained with an equation of the form $V = bx + a$
but the gain would be offset by disadvantages of adding the constant.

DERIVATION OF REGRESSION COEFFICIENTS

The regression coefficients were derived from an analysis of stand-
ard conventional volume tables in the following manner:

1. Total volumes and heights were summed by diameter class,
   generally using the full range of height classes shown in
   the tables.

2. Preliminary regression coefficients for each diameter class
   were derived by the formula

$$b = \frac{\leq v}{D^2 \dfrac{\leq H}{100}}$$

where v = volume of individual trees
      H = height of individual trees
      D = 1-inch diameter class

The coefficients were plotted on ordinary cross section paper over diameter class on a vertical scale that permitted reading directly to 3 places. Freehand curves drawn through these points formed a well-defined pattern, with values descending sharply from the 10- to 40-inch class and more gradual above the 40-inch class. Ponderosa pine was a notable exception in that after dipping downward in the customary manner, the coefficients increased slightly with increase in diameter. This may be explained in part at least by the fact that because of the characteristic flat-topped crowns of this species, total heights even though measured to the tip are low as compared to trees of normal top taper.

The coefficients read from the smoothed curve, i.e., the final coefficients of total cubic volume on $D^2H/100$ were next reduced to partial cubic volume coefficients by multiplying by the appropriate proportions (average by diameter class) of total cubic volume between a 1-foot stump and 4-inch top. These partial coefficients were then replotted over diameter and final values read from the smoothed curve by 0.1-inch diameter classes. In some cases such as for lodgepole pine and alpine fir, partial cubic volume tables were available and regression coefficients were computed directly from these tables.

Standard tables used to derive the regression coefficients follow:

Ponderosa pine
    Young growth   Table 32, USDA Tech. Bull. 630
    Old growth   Table 28, USDA Tech. Bull. 407

White pine
    Young growth   Table 35, USDA Tech. Bull. 323
    Old growth   Table 35 modified, and tree measurements

Douglas-fir
    Young growth   Table 39, USDA Tech. Bull. 323
    Old growth   Table 39 modified, and tree measurements

Western larch
    Young growth   Table 36, USDA Tech. Bull. 323
    Old growth   Table 36 modified, and tree measurements

Grand fir
    Young growth   Table 38, USDA Tech. Bull. 323
    Old growth   Table 38 modified, and tree measurements·

Lodgepole pine   Rocky Mountain Forest and Range Experiment Station. Preliminary cubic volume table for lodgepole pine, 1948, table 2 standard volume tables for lodgepole pine in Alberta. Forest Research Division Tech. note 9, 1955.

Western redcedar
        Young growth   Table 40, USDA Tech. Bull. 323
        Old growth   Table 40 modified, and tree measure-
                            ments

Alpine fir   Alpine fir table by Joye E. Smith,
                            4/5/50 from Rocky Mountain Forest and
                            Range Experiment Station files.

Western hemlock
        Young growth   Table 37, USDA Tech. Bull. 323
        Old growth   Table 37 modified, and tree measure-
                            ments

Spruce   Table 89, USDA
                            Volume tables for important timber
                            trees of the Western States. Part 1,
                            Western species.

Cottonwood   R-1 Forest Survey table

Aspen   R-1 Forest Survey table

Juniper   R-1 Forest Survey table

As indicated above, the regression coefficients are essentially
a means of translating acceptable conventional tables into formulas.
In a sense they might be considered as merely putting finer and more
easily determined graduations on previously used standards. In this
process some of the distinctions within diameter class of the original
tables were sacrificed for offsetting advantages. Actually, such fine
distinctions may be more apparent than real. Rather than to strive
for the unattainable absolute, a primary Forest Survey objective is to
measure change and it is believed that the coefficients accomplish
this by the same token that a scale may be in absolute error by 2
percent but still detect differences of a hair.

It should be noted, however, that since short trees tend to be
underscaled and tall trees overscaled, growth determinations tend to
be biased on the high side. This bias is small but can be measured
and appropriate corrections made as required.

Regression coefficients of partial cubic-foot volume[1] on $D^2H/100$
Young growth

DBH (inches)	Western white pine	Ponderosa pine	Western white larch	Douglas-fir	Grand fir	Spruce	Hemlock	Cedar	Lodgepole pine	Alpine fir	Juniper	Cotton-wood	Aspen
5.0	.079	.048	.046	.051	.076	.094	.065	.090	.105	.092	.060	.090	.110
5.1	.092	.055	.055	.068	.083	.100	.070	.097	.116	.107	.079	.097	.121
5.2	.104	.063	.064	.082	.090	.107	.075	.105	.127	.118	.092	.103	.130
5.3	.114	.070	.072	.093	.097	.113	.080	.111	.137	.127	.103	.107	.138
5.4	.123	.077	.080	.103	.104	.119	.085	.118	.147	.134	.112	.112	.145
5.5	.130	.083	.087	.111	.112	.126	.090	.124	.157	.140	.120	.115	.151
5.6	.137	.089	.093	.118	.118	.132	.095	.130	.167	.146	.127	.119	.157
5.7	.143	.094	.099	.124	.125	.138	.100	.135	.175	.152	.132	.122	.162
5.8	.149	.100	.104	.130	.131	.143	.106	.140	.183	.157	.138	.126	.166
5.9	.154	.105	.109	.135	.137	.149	.111	.145	.191	.163	.143	.129	.170
6.0	.158	.110	.114	.140	.143	.154	.116	.150	.199	.168	.147	.132	.174
6.1	.162	.115	.118	.144	.149	.159	.122	.154	.205	.172	.151	.135	.178
6.2	.166	.119	.122	.147	.153	.164	.127	.158	.209	.175	.155	.137	.181
6.3	.170	.124	.126	.151	.159	.169	.132	.162	.213	.178	.159	.140	.184
6.4	.173	.128	.129	.155	.164	.173	.137	.165	.217	.180	.162	.143	.187
6.5	.177	.132	.133	.158	.168	.178	.143	.169	.220	.183	.165	.146	.190
6.6	.179	.135	.136	.161	.172	.183	.147	.172	.223	.185	.168	.148	.192
6.7	.182	.137	.139	.163	.176	.187	.151	.174	.225	.188	.171	.150	.195
6.8	.185	.140	.141	.166	.180	.191	.155	.177	.227	.190	.174	.153	.197
6.9	.187	.142	.143	.169	.183	.195	.158	.180	.229	.192	.177	.155	.199
7.0	.190	.144	.145	.171	.186	.199	.161	.182	.231	.194	.180	.158	.201
7.1	.192	.146	.147	.173	.190	.203	.164	.184	.233	.196	.182	.160	.203
7.2	.194	.148	.149	.175	.193	.206	.168	.186	.235	.197	.185	.162	.205
7.3	.196	.149	.151	.177	.196	.210	.170	.188	.236	.199	.187	.164	.207
7.4	.198	.151	.152	.179	.198	.213	.173	.190	.237	.200	.189	.167	.208
7.5	.200	.152	.154	.181	.201	.216	.176	.192	.238	.202	.191	.169	.210
7.6	.201	.153	.155	.183	.203	.217	.178	.193	.239	.203	.192	.171	.211
7.7	.203	.155	.156	.184	.204	.219	.179	.194	.240	.204	.193	.173	.212
7.8	.204	.156	.157	.185	.206	.220	.181	.195	.241	.205	.194	.174	.213
7.9	.205	.157	.159	.186	.208	.221	.183	.196	.242	.206	.195	.176	.215
8.0	.207	.159	.160	.187	.209	.222	.184	.197	.243	.207	.196	.178	.216
8.1	.208	.160	.161	.188	.210	.223	.185	.198	.244	.208	-	.180	.217
8.2	.209	.161	.162	-	.211	.224	.186	.199	.245	.208	.197	.181	.218
8.3	.210	.162	.163	.189	.212	.225	.188	.200	-	.209	.198	.183	-
8.4	.211	.163	.164	-	.213	.226	.189	-	-	.210	-	.184	.219
8.5	.212	.164	.165	.190	.214	.226	.190	.201	.246	.210	.199	.186	.220
8.6	.212	.165	.166	-	-	.227	.191	-	.246	.211	-	.187	-
8.7	.213	.166	-	.191	.215	-	.192	.202	.247	-	.200	.188	.221
8.8	.214	.167	.167	-	-	.228	.193	-	-	.212	-	.189	.222
8.9	-	-	.168	-	.216	-	-	.203	.248	-	.201	.190	-
9.0	.215	.168	-	-	-	.229	.194	-	-	.213	-	.191	.223
9.1	-	.169	.169	.192	.217	-	.195	-	-	-	.202	-	-
9.2	.216	.170	.170	-	-	.230	.196	.204	.249	.214	-	.192	-
9.3	-	.171	-	-	-	-	-	-	-	-	-	.193	-
9.4	.217	-	.171	-	.218	-	.197	-	-	-	.203	-	.224
9.5	-	.172	-	-	-	-	-	-	-	.215	-	.194	-
9.6	.218	.173	.172	-	-	-	.198	-	-	-	-	-	-
9.7	-	.174	-	-	-	.231	-	-	-	-	.204	.195	-
9.8	-	-	-	-	-	-	.199	-	-	-	-	-	-
9.9	.219	.175	.173	-	.219	-	.200	-	.250	-	.205	.196	-
10.0	-	.176	-	-	-	-	-	-	-	-	-	-	-
10.1	-	-	-	-	-	-	-	-	-	-	-	-	-
10.2	-	.177	.174	-	-	.232	.201	.203	.249	-	-	.197	-
10.3	-	.178	-	-	-	-	-	-	-	-	-	-	-
10.4	.220	-	.175	-	-	-	-	-	-	-	.206	-	-
10.5	-	.179	-	-	-	-	.202	-	-	-	-	-	-
10.6	-	-	-	-	-	-	-	-	-	-	-	-	-
10.7	-	.180	-	-	-	-	-	-	.248	-	-	.198	-
10.8	-	-	-	-	.220	-	-	.202	-	-	-	-	-
10.9	-	.181	-	-	-	-	.203	-	-	-	-	-	-
11.0	-	.182	.176	-	-	-	-	-	.247	-	.207	-	-
11.1	-	-	-	-	-	-	-	-	-	-	-	-	-
11.2	-	.183	-	-	-	-	-	.201	-	.214	-	-	-
11.3	.219	-	-	.191	-	-	-	-	.246	-	-	.199	-
11.4	-	-	-	-	-	-	-	-	-	-	-	-	-
11.5	-	.184	-	-	-	-	-	.200	-	.213	-	-	-

Continued

DBH (inches)	Western white pine	Ponder-osa pine	Western white larch	Douglas-fir	Grand fir	Spruce	Hemlock	Cedar	Lodge-pole pine	Alpine fir	Juniper	Cotton-wood	Aspen
11.6	-	-	-	-	-	-	-	-	.245	-	-	-	-
11.7	-	.185	-	-	-	-	-	-	-	-	-	-	-
11.8	-	-	-	-	-	-	-	.199	-	.212	-	-	-
11.9	-	-	.177	-	-	-	-	-	.244	-	-	.200	-
12.0	-	.186	-	-	-	-	-	-	-	-	-	-	-
12.1	.218	-	-	-	-	.231	-	.198	-	-	-	-	-
12.2	-	-	-	-	-	-	-	-	-	.211	-	-	-
12.3	-	.187	-	.190	-	-	.204	-	.243	-	-	-	-
12.4	-	-	-	-	-	-	-	.197	-	-	-	-	-
12.5	-	-	-	-	-	-	-	-	-	.210	-	-	-
12.6	.217	-	-	-	-	.230	-	-	.242	-	-	-	-
12.7	-	.188	-	-	-	-	-	.196	-	-	-	-	-
12.8	-	-	-	-	-	-	-	-	-	-	-	-	-
12.9	-	-	-	-	.219	-	-	-	.241	.209	-	-	-
13.0	-	-	-	-	-	-	-	.195	-	-	-	-	-
13.1	.216	.189	-	.189	-	.229	-	-	-	-	-	-	-
13.2	-	-	-	-	-	-	-	-	.240	.208	-	-	-
13.3	-	-	-	-	-	-	-	.194	-	-	-	.201	-
13.4	-	.190	-	-	-	.228	-	-	-	.207	-	-	-
13.5	-	-	-	-	-	-	-	-	.239	-	-	-	-
13.6	.215	-	-	.188	-	-	-	.193	-	-	-	-	-
13.7	-	-	-	-	-	-	-	-	-	.206	-	-	-
13.8	-	-	-	-	-	.227	-	-	.238	-	-	-	-
13.9	-	.191	-	-	-	-	-	.192	-	.205	-	-	-
14.0	-	-	.176	-	-	-	-	-	-	-	-	-	-
14.1	.214	-	-	-	-	.226	-	-	-	-	-	-	-
14.2	-	-	-	.187	-	-	-	.191	.237	.204	-	-	-
14.3	-	.192	-	-	-	-	-	-	-	-	-	-	-
14.4	-	-	-	-	-	-	-	-	-	.202	-	-	-
14.5	.213	-	-	-	-	.225	-	.190	.236	-	-	-	-
14.6	-	-	-	-	-	-	-	-	-	-	-	-	-
14.7	-	-	-	.186	-	-	.205	-	-	.201	-	-	-
14.8	-	.193	-	-	-	-	-	.189	.235	-	-	-	-
14.9	-	-	-	-	-	.224	-	-	-	.200	-	-	.223
15.0	.212	-	-	-	-	-	-	-	-	-	-	-	-
15.1	-	-	-	.185	-	-	-	.188	.234	-	-	-	-
15.2	-	-	.175	-	-	-	-	-	-	-	-	-	-
15.3	-	-	-	-	-	.223	-	-	-	.199	-	-	-
15.4	-	.194	-	-	.218	-	-	.187	.233	-	-	-	-
15.5	.211	-	-	-	-	-	-	-	-	-	.208	-	-
15.6	-	-	-	-	-	-	-	-	-	.198	-	-	-
15.7	-	-	-	.184	-	.222	-	.186	.232	-	-	-	-
15.8	-	-	-	-	-	-	-	-	-	.197	-	-	-
15.9	.210	-	-	-	-	-	-	-	-	-	-	-	-
16.0	-	.195	.174	-	-	.221	-	.185	-	-	-	-	-
16.1	-	-	-	-	-	-	-	-	.231	.196	-	-	-
16.2	-	-	-	.183	-	-	-	-	-	-	-	-	-
16.3	-	-	-	-	-	-	-	.184	.230	.195	-	-	-
16.4	-	-	-	-	-	.220	-	-	-	-	-	-	-
16.5	.209	-	-	-	-	-	-	-	-	-	-	-	-
16.6	-	-	-	-	-	-	-	.183	-	.194	-	-	-
16.7	-	-	.173	.182	-	-	-	-	.229	-	-	-	-
16.8	-	-	-	-	-	.219	-	-	-	.193	-	-	-
16.9	.208	.196	-	-	-	-	-	.182	-	-	-	-	-
17.0	-	-	-	-	-	-	-	-	-	-	-	-	-
17.1	-	-	-	-	-	-	-	-	.228	.192	-	-	-
17.2	-	-	.172	.181	-	.218	-	-	-	-	-	-	.222
17.3	.207	-	-	-	-	-	-	.181	.227	.191	-	-	-
17.4	-	-	-	-	-	-	-	-	-	-	-	-	-
17.5	-	-	-	-	-	-	.206	-	-	-	-	-	-
17.6	-	-	-	.180	-	.217	-	.180	.226	.190	-	-	-
17.7	-	.197	.171	-	-	-	-	-	-	-	-	-	-
17.8	.206	-	-	-	-	-	-	-	-	.189	-	-	-
17.9	-	-	-	-	-	-	-	.179	.225	-	-	-	-
18.0	-	-	-	-	.217	.216	-	-	-	.188	-	-	-
18.1	-	-	-	.179	-	-	-	-	-	-	-	-	-
18.2	-	-	.170	-	-	-	-	.178	.224	-	-	-	-

Continued

DBH (inches)	Western white pine	Ponderosa pine	Western white larch	Douglas-fir	Grand fir	Spruce	Hemlock	Cedar	Lodge-pole pine	Alpine fir	Juniper	Cotton-wood	Aspen
18.3	.205	-	-	-	-	-	-	-	-	.187	-	-	-
18.4	-	-	-	-	-	.215	-	-	-	-	-	-	-
18.5	-	.198	-	-	-	-	-	.177	.223	.186	-	-	-
18.6	-	-	-	.178	-	-	-	-	-	-	-	-	-
18.7	.204	-	.169	-	-	-	-	-	-	-	-	-	-
18.8	-	-	-	-	-	-	-	-	.222	.185	-	-	-
18.9	-	-	-	-	-	.214	-	.176	-	-	-	-	-
19.0	-	-	-	-	-	-	-	-	-	.184	-	-	.221
19.1	-	-	.168	.177	-	-	-	-	-	-	-	-	-
19.2	.203	-	-	-	-	-	-	.175	.221	.183	-	-	-
19.3	-	-	-	-	-	.213	-	-	-	-	-	-	-
19.4	-	-	-	-	-	-	-	-	-	-	-	-	-
19.5	-	.199	-	-	-	-	-	.174	.220	.182	-	-	-
19.6	.202	-	.167	.176	-	-	-	-	-	-	-	-	-
19.7	-	-	-	-	-	.212	-	-	-	.181	-	-	-
19.8	-	-	-	-	-	-	-	-	.219	-	-	-	-
19.9	-	-	-	-	-	-	-	.173	-	.180	-	-	-
20.0	-	-	.166	.175	-	-	-	-	-	-	-	-	-
20.1	.201	-	-	-	-	-	-	-	.218	.179	-	-	-
20.2	-	-	-	-	-	.211	-	.172	-	-	-	-	-
20.3	-	-	.165	-	-	-	-	-	-	.178	-	-	-
20.4	-	-	-	-	-	-	-	-	.217	-	-	-	.220
20.5	.200	-	-	.174	-	-	-	-	-	.177	-	-	-
20.6	-	-	-	-	-	.210	-	.171	-	-	-	-	-
20.7	-	-	-	-	.216	-	-	-	.216	.176	-	-	-
20.8	-	.200	.164	-	-	-	-	.170	-	-	-	-	-
20.9	.199	-	-	-	-	-	-	-	-	.175	-	-	-

1/ Volume between 1-foot stump and 4-inch inside bark top diameter.

Regression coefficients of partial cubic-foot volume[1] on $D^2H/100$
Old growth

DBH (inches)	Western white pine	Ponderosa pine	Western white larch	Douglas-fir	Grand fir	Spruce	Hemlock	Cedar	Lodgepole pine	Alpine fir	Juniper	Cottonwood	Aspen
18.0	.208	.197	.181	.189	.227	.221	.218	.177	.225	.188	–	.201	.222
18.1	.208	–	–	–	–	.220	–	–	–	–	–	–	–
18.2	.207	–	–	–	–	–	–	–	.224	–	–	–	–
18.3	.207	–	.180	.188	.226	–	–	.176	–	.187	–	–	–
18.4	–	–	–	–	–	–	–	–	–	–	–	–	–
18.5	–	–	–	–	–	–	–	–	.223	.186	–	–	–
18.6	–	–	–	–	–	.219	–	–	–	–	–	–	–
18.7	–	.198	–	.187	–	–	–	.175	–	–	–	–	–
18.8	–	–	–	–	.225	–	–	–	.222	.185	–	–	–
18.9	–	–	.179	–	–	–	.217	–	–	–	–	–	–
19.0	–	–	–	–	–	–	–	–	–	.184	–	–	–
19.1	–	–	–	–	–	.218	–	.174	–	–	–	–	–
19.2	–	–	–	–	–	–	–	–	.221	.183	–	–	.221
19.3	–	–	.178	–	–	–	–	–	–	–	–	–	–
19.4	.206	–	–	–	.224	–	–	–	–	–	–	–	–
19.5	–	–	–	.186	–	–	–	.173	.220	.182	–	–	–
19.6	–	–	–	–	–	.217	–	–	–	–	–	–	–
19.7	–	–	–	–	–	–	–	–	–	.181	–	–	–
19.8	–	–	.177	–	–	–	–	–	.219	–	–	–	–
19.9	–	.199	–	–	–	–	–	.172	–	.180	–	–	–
20.0	–	–	–	–	.223	–	–	–	–	–	–	–	–
20.1	–	–	–	.185	–	–	–	–	.218	.179	–	–	–
20.2	–	–	.176	–	–	.216	–	–	–	–	–	–	–
20.3	–	–	–	–	–	–	–	.171	–	.178	–	–	–
20.4	–	–	–	–	–	–	·–	–	.217	–	–	–	–
20.5	–	–	–	–	–	–	–	–	–	.177	–	–	–
20.6	.205	–	.175	–	.222	–	–	–	–	–	–	–	–
20.7	–	–	–	.184	–	.215	–	.170	.216	.176	–	–	–
20.8	–	–	–	–	–	–	–	–	–	–	–	–	–
20.9	–	–	–	–	–	–	–	–	–	.175	–	–	–
21.0	–	–	–	–	–	–	–	–	–	–	–	–	–
21.1	–	.200	.174	–	–	–	–	.169	–	–	–	–	–
21.2	–	–	–	–	.221	.214	.216	–	.215	.174	–	–	.220
21.3	–	–	–	–	–	–	–	–	–	–	–	–	–
21.4	–	–	–	.183	–	–	–	–	–	–	–	–	–
21.5	–	–	.173	–	–	–	–	.168	–	.173	–	–	–
21.6	–	–	–	–	.220	.213	–	–	.214	–	–	–	–
21.7	–	–	–	–	–	–	–	–	–	.172	–	–	–
21.8	–	–	–	–	–	–	–	–	–	–	–	–	–
21.9	–	–	–	–	–	–	–	–	.213	–	–	–	–
22.0	–	–	.172	–	–	–	–	.167	–	.171	–	–	–
22.1	.204	–	–	.182	–	.212	–	–	–	–	–	–	–
22.2	–	–	–	–	–	–	–	–	–	.170	–	–	–
22.3	–	.201	–	–	.219	–	–	–	.212	–	–	–	–
22.4	–	–	–	–	–	–	–	–	–	–	–	–	–
22.5	–	–	.171	–	–	–	–	.166	–	.169	–	–	–
22.6	–	–	–	–	–	.211	–	–	.211	–	–	–	–
22.7	–	–	–	–	–	–	–	–	–	.168	–	–	–
22.8	–	–	–	.181	–	–	–	–	–	–	–	–	–
22.9	–	–	.170	–	.218	–	–	.165	–	–	–	–	–
23.0	–	–	–	–	–	–	–	–	.210	.167	–	–	–
23.1	–	–	–	–	–	.210	–	–	–	–	–	–	–
23.2	–	–	–	–	–	–	.215	–	–	–	–	–	–
23.3	–	–	–	–	–	–	–	–	–	.166	–	–	–
23.4	–	–	.169	–	–	–	–	–	–	–	–	–	–
23.5	.203	–	–	.180	.217	–	–	.164	.209	–	–	–	–
23.6	–	.202	–	–	–	–	–	–	–	.165	–	–	–
23.7	–	–	–	–	–	.209	–	–	–	–	–	–	–
23.8	–	–	–	–	–	–	–	–	–	–	–	–	–
23.9	–	–	.168	–	–	–	–	–	.208	.164	–	–	.219
24.0	–	–	–	–	–	–	–	.163	–	–	–	–	–
24.1	–	–	–	–	.216	–	–	–	–	–	–	–	–
24.2	–	–	–	–	–	.208	–	–	–	.163	–	–	–
24.3	–	–	.167	–	–	–	–	–	–	–	–	–	–
24.4	–	–	–	.179	–	–	–	–	.207	–	–	–	–
24.5	–	–	–	–	–	–	–	–	–	.162	–	–	–

Continued

DBH (inches)	Western white pine	Ponderosa pine	Western white larch	Douglas-fir	Grand fir	Spruce	Hemlock	Cedar	Lodgepole pine	Alpine fir	Juniper	Cottonwood	Aspen
24.6	-	-	-	-	-	-	-	.162	-	-	-	.200	-
24.7	-	-	.166	-	.215	.207	-	-	-	-	-	-	-
24.8	.202	-	-	-	-	-	-	-	-	-	-	-	-
24.9	-	.203	-	-	-	-	-	-	-	.161	-	-	-
25.0	-	-	-	-	-	-	-	-	.206	-	-	-	-
25.1	-	-	-	-	-	.206	-	-	-	-	-	-	-
25.2	-	-	.165	.178	-	-	-	.161	-	-	-	-	-
25.3	-	-	-	-	-	-	-	-	-	.160	-	-	-
25.4	-	-	-	-	.214	-	-	-	-	-	-	-	-
25.5	-	-	-	-	-	-	-	-	-	-	-	-	-
25.6	-	-	-	-	-	.205	.214	-	.205	-	-	-	-
25.7	-	-	.164	-	-	-	-	.160	-	.159	-	-	-
25.8	-	-	-	-	-	-	-	-	-	-	-	-	-
25.9	-	-	-	-	-	-	-	-	-	-	-	-	-
26.0	-	-	-	.177	.213	-	-	-	-	.158	-	-	-
26.1	-	.204	.163	-	-	.204	-	-	-	-	-	-	-
26.2	-	-	-	-	-	-	-	-	-	-	-	-	-
26.3	.201	-	-	-	-	-	-	-	-	-	-	-	-
26.4	-	-	-	-	-	-	-	-	-	.157	-	-	-
26.5	-	-	.162	-	-	-	-	.159	.204	-	-	-	-
26.6	-	-	-	-	-	.203	-	-	-	-	-	-	-
26.7	-	-	-	-	.212	-	-	-	-	.156	-	-	-
26.8	-	-	-	-	-	-	-	-	-	-	-	-	-
26.9	-	-	-	-	-	-	-	-	-	-	-	-	-
27.0	-	-	.161	.176	-	-	-	-	-	.155	-	-	.218
27.1	-	-	-	-	-	.202	-	-	-	-	-	-	-
27.2	-	-	-	-	-	-	-	-	-	-	-	-	-
27.3	-	.205	-	-	-	-	-	.158	-	-	-	-	-
27.4	-	-	-	-	-	-	-	-	-	.154	-	-	-
27.5	-	-	.160	-	.211	-	-	-	.203	-	-	-	-
27.6	-	-	-	-	-	.201	-	-	-	-	-	-	-
27.7	-	-	-	-	-	-	-	-	-	.153	-	-	-
27.8	.200	-	-	-	-	-	.213	-	-	-	-	-	-
27.9	-	-	-	.175	-	-	-	-	-	-	-	-	-
28.0	-	-	.159	-	-	-	-	-	-	-	-	-	-
28.1	-	-	-	-	-	.200	-	.157	-	-	-	-	-
28.2	-	-	-	-	.210	-	-	-	-	.152	-	-	-
28.3	-	-	-	-	-	-	-	-	-	-	-	-	-
28.4	-	-	-	-	-	-	-	-	-	-	-	-	-
28.5	-	.206	.158	-	-	-	-	-	-	-	-	-	-
28.6	-	-	-	-	-	.199	-	-	.202	.151	-	.199	-
28.7	-	-	-	-	-	-	-	-	-	-	-	-	-
28.8	-	-	-	-	-	-	-	-	-	-	-	-	-
28.9	-	-	.157	.174	-	-	-	.156	-	.150	-	-	-
29.0	-	-	-	-	-	-	-	-	-	-	-	-	-
29.1	-	-	-	-	.209	.198	-	-	-	-	-	-	-
29.2	-	-	-	-	-	-	-	-	-	-	-	-	-
29.3	-	-	-	-	-	-	-	-	-	-	-	-	-
29.4	-	-	.156	-	-	-	-	-	-	.149	-	-	-
29.5	-	-	-	-	-	-	-	-	-	-	-	-	-
29.6	-	.207	-	-	-	.197	-	-	-	-	-	-	-
29.7	-	-	-	-	-	-	-	-	-	-	-	-	-
29.8	-	-	-	-	-	-	-	.155	-	.148	-	-	-
29.9	-	-	.155	.173	-	-	.212	-	-	-	-	-	-
30.0	.199	-	-	-	.208	-	-	-	-	-	-	-	-
30.1	-	-	-	-	-	.196	-	-	-	-	-	-	-
30.2	-	-	-	-	-	-	-	-	-	.147	-	-	-
30.3	-	-	-	-	-	-	-	-	-	-	-	-	-
30.4	-	-	.154	-	-	-	-	-	.201	-	-	-	-
30.5	-	-	-	-	-	-	-	-	-	-	-	-	-
30.6	-	-	-	-	-	.195	-	-	-	.146	-	-	-
30.7	-	-	-	-	-	-	-	-	-	-	-	-	-
30.8	-	-	-	-	-	-	-	-	-	-	-	.198	.217
30.9	-	.208	.153	-	.207	-	-	.154	-	-	-	-	-
31.0	-	-	-	.172	-	-	-	-	-	.145	-	-	-
31.1	-	-	-	-	-	.194	-	-	-	-	-	-	-

Continued

DBH (inches)	Western white pine	Ponderosa pine	Western white larch	Douglas-fir	Grand fir	Spruce	Hemlock	Cedar	Lodgepole pine	Alpine fir	Juniper	Cottonwood	Aspen
31.2	–	–	–	–	–	–	–	–	–	–	–	–	–
31.3	–	–	–	–	–	–	–	–	–	–	–	–	–
31.4	–	–	–	–	–	–	–	–	–	.144	–	–	–
31.5	–	–	.152	–	–	–	–	–	–	–	–	–	–
31.6	–	–	–	–	–	.193	–	.	–	–	–	–	–
31.7	–	–	–	–	–	–	–	–	–	–	–	–	–
31.8	–	–	–	–	–	–	–	–	–	.143	–	–	–
31.9	–	–	–	–	.206	–	–	–	–	–	–	–	–
32.0	–	–	.151	–	–	–	–	–	–	–	–	–	–
32.1	–	.209	–	–	–	.192	.211	.153	–	–	–	–	–
32.2	–	–	–	–	–	–	–	–	–	.142	–	–	–
32.3	.198	–	–	–	–	–	–	–	–	–	–	–	–
32.4	–	–	–	.171	–	–	–	–	–	–	–	–	–
32.5	–	–	.150	–	–	–	–	–	–	–	–	–	–
32.6	–	–	–	–	–	.191	–	–	–	.141	–	–	–
32.7	–	–	–	–	–	–	–	–	–	–	–	–	–
32.8	–	–	–	–	–	–	–	–	–	–	–	–	–
32.9	–	–	–	–	.205	–	–	–	–	–	–	–	–
33.0	–	–	.149	–	–	–	–	–	–	–	–	–	–
33.1	–	–	–	–	–	.190	–	–	–	.140	–	–	–
33.2	–	.210	–	–	–	–	–	–	–	–	–	–	–
33.3	–	–	–	–	–	–	–	–	–	–	–	.197	–
33.4	–	–	–	–	–	–	–	–	–	–	–	–	–
33.5	–	–	–	–	–	–	–	–	–	–	–	–	–
33.6	–	–	.148	.170	–	.189	–	.152	–	.139	–	–	–
33.7	–	–	–	–	–	–	–	–	–	–	–	–	–
33.8	–	–	–	–	–	–	–	–	–	–	–	–	–
33.9	–	–	–	–	–	–	–	–	–	–	–	–	–
34.0	–	–	–	–	–	–	–	–	–	.138	–	–	–
34.1	–	–	.147	–	–	–	–	–	–	–	–	–	–
34.2	–	–	–	–	–	.188	–	–	–	–	–	–	–
34.3	–	–	–	–	–	–	–	–	–	–	–	–	–
34.4	–	–	–	–	.204	–	–	–	–	.137	–	–	–
34.5	–	–	–	–	–	–	–	–	–	–	–	–	–
34.6	–	.211	–	–	–	–	–	–	–	–	–	–	–
34.7	–	–	–	–	–	.187	–	–	–	–	–	–	–
34.8	–	–	.146	–	–	–	–	–	–	.136	–	–	–
34.9	–	–	–	–	–	–	–	–	–	–	–	–	–
35.0	–	–	–	–	–	–	–	–	–	–	–	–	–
35.1	–	–	–	–	–	–	–	.151	–	–	–	–	–
35.2	.197	–	–	–	–	.186	–	–	–	.135	–	–	–
35.3	–	–	.145	–	–	–	–	–	–	–	–	–	–
35.4	–	–	–	–	–	–	–	–	–	–	–	–	–
35.5	–	–	–	–	–	–	–	–	–	–	–	–	–
35.6	–	.212	–	.169	–	–	–	–	–	.134	–	–	–
35.7	–	–	–	–	–	–	–	–	–	–	–	.196	–
35.8	–	–	–	–	–	.185	–	–	–	–	–	–	–
35.9	–	–	.144	–	.203	–	–	–	–	–	–	–	–
36.0	–	–	–	–	–	–	–	–	–	.133	–	–	–
36.1	–	–	–	–	–	–	–	–	–	–	–	–	–
36.2	–	–	–	–	–	–	–	–	–	–	–	–	–
36.3	–	–	–	–	–	–	–	–	–	–	–	–	–
36.4	–	–	–	–	–	–	–	–	–	.132	–	–	–
36.5	–	–	.143	–	–	.184	–	–	–	–	–	–	–
36.6	–	–	–	–	–	–	–	–	–	–	–	–	–
36.7	–	.213	–	–	–	–	–	.150	–	–	–	–	–
36.8	–	–	–	–	–	–	–	–	–	–	–	–	–
36.9	–	–	–	–	–	–	–	–	–	.131	–	–	–
37.0	–	–	–	–	–	–	–	–	–	–	–	–	–
37.1	–	–	–	–	–	–	–	–	–	–	–	–	–
37.2	–	–	.142	–	–	–	–	–	–	–	–	–	–
37.3	–	–	–	–	–	–	–	–	–	–	–	–	–
37.4	–	–	–	–	–	.183	–	–	–	.130	–	–	–
37.5	–	–	–	–	–	–	–	–	–	–	–	–	–
37.6	–	–	–	–	–	–	–	–	–	–	–	–	–
37.7	–	–	–	–	–	–	–	–	–	–	–	–	–
37.8	–	.214	–	–	.202	–	–	–	–	.129	–	–	–

Continued

DBH (inches)	Western white pine	Ponderosa pine	Western white larch	Douglas-fir	Grand fir	Spruce	Hemlock	Cedar	Lodgepole pine	Alpine fir	Juniper	Cottonwood	Aspen
37.9	–	–	.141	–	–	–	–	–	–	–	–	–	–
38.0	–	–	–	–	–	–	–	–	–	–	–	.195	–
38.1	–	–	–	–	–	–	–	–	–	–	–	–	–
38.2	–	–	–	.168	–	–	–	–	–	–	–	–	–
38.3	–	–	–	–	–	.182	–	–	–	.128	–	–	–
38.4	–	–	–	–	–	–	–	–	–	–	–	–	–
38.5	–	–	.140	–	–	–	–	–	–	–	–	–	–
38.6	–	–	–	–	–	–	–	–	–	–	–	–	–
38.7	–	–	–	–	–	–	–	–	–	–	–	–	–
38.8	–	.215	–	–	–	–	–	–	–	.127	–	–	–
38.9	–	–	–	–	–	–	–	.149	–	–	–	–	–
39.0	–	–	–	–	–	–	–	–	–	–	–	–	–
39.1	–	–	–	–	–	–	–	–	–	–	–	–	–
39.2	–	–	–	–	–	–	–	–	–	–	–	–	–
39.3	–	–	.139	–	–	.181	–	–	–	.126	–	–	–
39.4	–	–	–	–	–	–	–	–	–	–	–	–	–
39.5	–	–	–	–	–	–	–	–	–	–	–	–	–
39.6	.196	–	–	–	.201	–	–	–	–	–	–	–	–
39.7	–	–	–	–	–	–	–	–	–	–	–	–	–
39.8	–	–	–	–	–	–	–	–	–	.125	–	–	–
39.9	–	.216	–	–	–	–	–	–	–	–	–	–	–
40.0	–	–	–	–	–	–	–	–	–	–	–	–	–
40.1	–	–	.138	–	–	–	–	–	–	–	–	–	–
40.2	–	–	–	–	–	–	–	–	–	–	–	–	–
40.3	–	–	–	–	–	–	–	–	–	–	–	–	–
40.4	–	–	–	–	–	–	–	–	–	–	–	.194	–
40.5	–	–	–	–	–	–	–	–	–	–	–	–	–
40.6	–	–	–	–	–	–	–	–	–	–	–	–	–
40.7	–	–	–	–	–	–	–	–	–	–	–	–	–
40.8	–	–	–	–	–	.180	–	–	–	–	–	–	–
40.9	–	.217	.137	–	–	–	–	–	–	–	–	–	–
41.0	–	–	–	–	–	–	–	.148	–	–	–	–	–
41.1	–	–	–	.167	–	–	–	–	–	–	–	–	–
41.2	–	–	–	–	–	–	–	–	–	–	–	–	–
41.3	–	–	–	–	–	–	–	–	–	–	–	–	–
41.4	–	–	–	–	–	–	–	–	–	–	–	–	–
41.5	–	–	–	–	–	–	–	–	–	–	–	–	–
41.6	–	–	–	–	–	–	–	–	–	–	–	–	–
41.7	–	–	–	–	–	–	–	–	–	–	–	–	–
41.8	–	–	–	–	.200	–	–	–	–	–	–	–	–
41.9	–	–	.136	–	–	–	–	–	–	–	–	–	–
42.0	–	.218	–	–	–	–	–	–	–	–	–	–	–
42.1	–	–	–	–	–	–	–	–	–	–	–	–	–
42.2	–	–	–	–	–	–	–	–	–	–	–	–	–
42.3	–	–	–	–	–	–	–	–	–	–	–	–	–
42.4	–	–	–	–	–	–	–	–	–	–	–	–	–
42.5	–	–	–	–	–	–	–	–	–	–	–	–	–
42.6	–	–	–	–	–	.179	–	–	–	–	–	–	–
42.7	–	–	–	–	–	–	–	–	–	–	–	–	–
42.8	–	–	–	–	–	–	–	–	–	–	–	.193	–
42.9	–	–	.135	–	–	–	–	–	–	–	–	–	–
43.0	–	–	–	–	–	–	–	–	–	–	–	–	–
43.1	–	–	–	–	–	–	–	–	–	–	–	–	–
43.2	–	.219	–	–	–	–	–	–	–	–	–	–	–
43.3	–	–	–	–	–	–	–	–	–	–	–	–	–
43.4	–	–	–	–	–	–	–	–	–	–	–	–	–
43.5	–	–	–	–	–	–	–	–	–	–	–	–	–
43.6	–	–	–	–	–	–	–	–	–	–	–	–	–
43.7	–	–	–	–	–	–	–	–	–	–	–	–	–
43.8	–	–	–	–	–	–	–	.147	–	–	–	–	–
43.9	–	–	–	–	–	–	–	–	–	–	–	–	–
44.0	–	.220	–	–	–	–	–	–	–	–	–	–	–
44.1	–	–	.134	–	–	–	–	–	–	–	–	–	–
44.2	–	–	–	–	–	.178	–	–	–	–	–	–	–
44.3	–	–	–	–	–	–	–	–	–	–	–	–	–
44.4	–	–	–	–	–	–	–	–	–	–	–	–	–

Continued

DBH (inches)	Western white pine	Ponderosa pine	Western white larch	Douglas-fir	Grand fir	Spruce	Hemlock	Cedar	Lodgepole pine	Alpine fir	Juniper	Cotton-wood	Aspen
44.5	-	-	-	-	-	-	-	-	-	-	-	-	-
44.6	-	-	-	-	-	-	-	-	-	-	-	-	-
44.7	-	-	-	-	-	-	-	-	-	-	-	-	-
44.8	-	-	-	-	-	-	-	-	-	-	-	-	-
44.9	-	-	-	-	.199	-	-	-	-	-	-	-	-
45.0	-	-	-	.166	-	-	-	-	-	-	-	-	-
45.1	-	-	-	-	-	-	-	-	-	-	-	-	-
45.2	-	.221	-	-	-	-	-	-	-	-	-	.192	-
45.3	-	-	-	-	-	-	-	-	-	-	-	-	-
45.4	-	-	-	-	-	-	-	-	-	-	-	-	-
45.5	-	-	-	-	-	-	-	-	-	-	-	-	-
45.6	-	-	-	-	-	-	-	-	-	-	-	-	-
45.7	-	-	-	-	-	-	-	-	-	-	-	-	-
45.8	-	-	.133	-	-	-	-	-	-	-	-	-	-
45.9	-	-	-	-	-	-	-	-	-	-	-	-	-
46.0	-	-	-	-	-	.177	-	-	-	-	-	-	-
46.1	.195	.222	-	-	-	-	-	-	-	-	-	-	-
46.2	-	-	-	-	-	-	-	-	-	-	-	-	-
46.3	-	-	-	-	-	-	-	-	-	-	-	-	-
46.4	-	-	-	-	-	-	-	-	-	-	-	-	-
46.5	-	-	-	-	-	-	-	-	-	-	-	-	-
46.6	-	-	-	-	-	-	-	-	-	-	-	-	-
46.7	-	-	-	-	-	-	-	-	-	-	-	-	-
46.8	-	-	-	-	-	-	-	-	-	-	-	-	-
46.9	-	-	-	-	-	-	-	-	-	-	-	-	-
47.0	-	-	-	-	-	-	-	-	-	-	-	-	-
47.1	-	-	-	-	-	-	-	-	-	-	-	-	-
47.2	-	.223	-	-	-	-	-	-	-	-	-	-	-
47.3	-	-	-	-	-	-	-	-	-	-	-	.191	-
47.4	-	-	.132	-	-	-	-	-	-	-	-	-	-
47.5	-	-	-	-	-	-	-	-	-	-	-	-	-
47.6	-	-	-	-	-	-	-	-	-	-	-	-	-
47.7	-	-	-	-	-	-	-	-	-	-	-	-	-
47.8	-	-	-	-	-	.176	-	-	-	-	-	-	-
47.9	-	-	-	-	-	-	-	-	-	-	-	-	-
48.0	-	-	-	-	-	-	-	-	-	-	-	-	-
48.1	-	.224	-	-	-	-	-	-	-	-	-	-	-
48.2	-	-	-	-	-	-	-	-	-	-	-	-	-
48.3	-	-	-	-	-	-	-	-	-	-	-	-	-
48.4	-	-	-	-	-	-	-	-	-	-	-	-	-
48.5	-	-	-	-	-	-	-	-	-	-	-	-	-
48.6	-	-	-	-	-	-	-	-	-	-	-	-	-
48.7	-	-	-	-	-	-	-	-	-	-	-	-	-
48.8	-	-	-	-	.198	-	-	-	-	-	-	-	-
48.9	-	-	-	-	-	-	-	-	-	-	-	-	-
49.0	-	-	-	-	-	-	-	-	-	-	-	-	-
49.1	-	-	-	-	-	-	-	-	-	-	-	-	-
49.2	-	-	-	-	-	-	-	-	-	-	-	-	-
49.3	-	.225	-	-	-	-	-	-	-	-	-	.190	-
49.4	-	-	-	-	-	-	-	-	-	-	-	-	-
49.5	-	-	-	-	-	-	-	-	-	-	-	-	-
49.6	-	-	-	-	-	-	-	-	-	-	-	-	-
49.7	-	-	-	-	-	.175	-	-	-	-	-	-	-
49.8	-	-	-	-	-	-	-	-	-	-	-	-	-
49.9	-	-	-	-	-	-	-	-	-	-	-	-	-
50.0	.195	.225	.132	.166	.198	.175	.211	.147	-	-	-	.190	-

1/ Volume between 1-foot stump and 4-inch inside bark top diameter.